



## Life Cycle Assessment of electricity generation: overview and methodological issues

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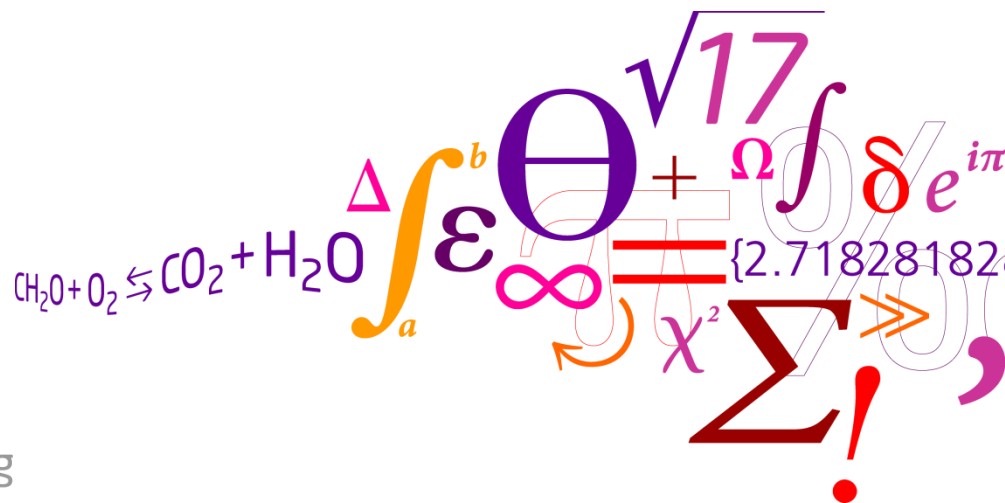
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# Life Cycle Assessment of electricity generation: overview and methodological issues

Roberto Turconi, Alessio Boldrin, Thomas Astrup

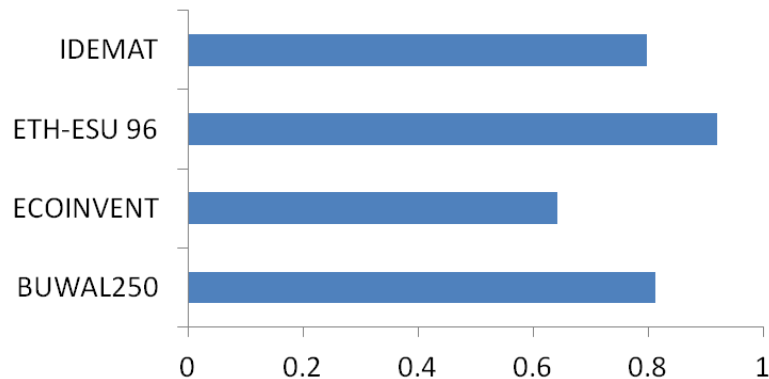
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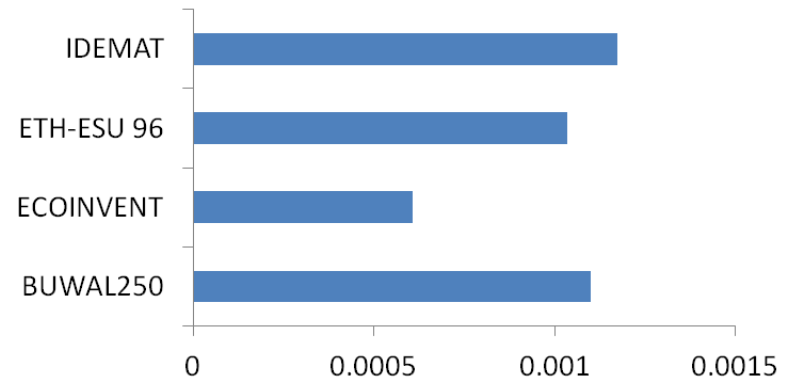
# Background

Electricity from natural gas, avg. UCTE plant (impacts per kWh)

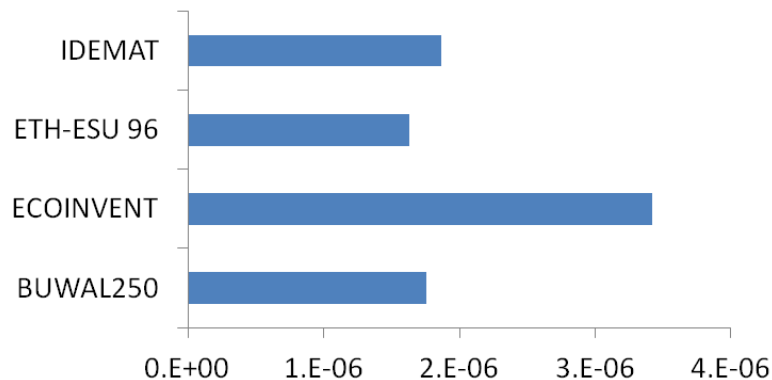
Climate change kg CO<sub>2</sub> eq



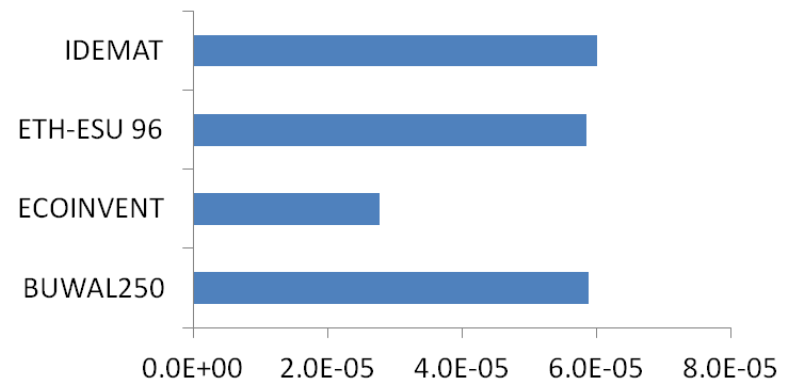
Terrestrial acidification kg SO<sub>2</sub> eq



Freshwater eutrophication kg P eq



Marine eutrophication kg N eq



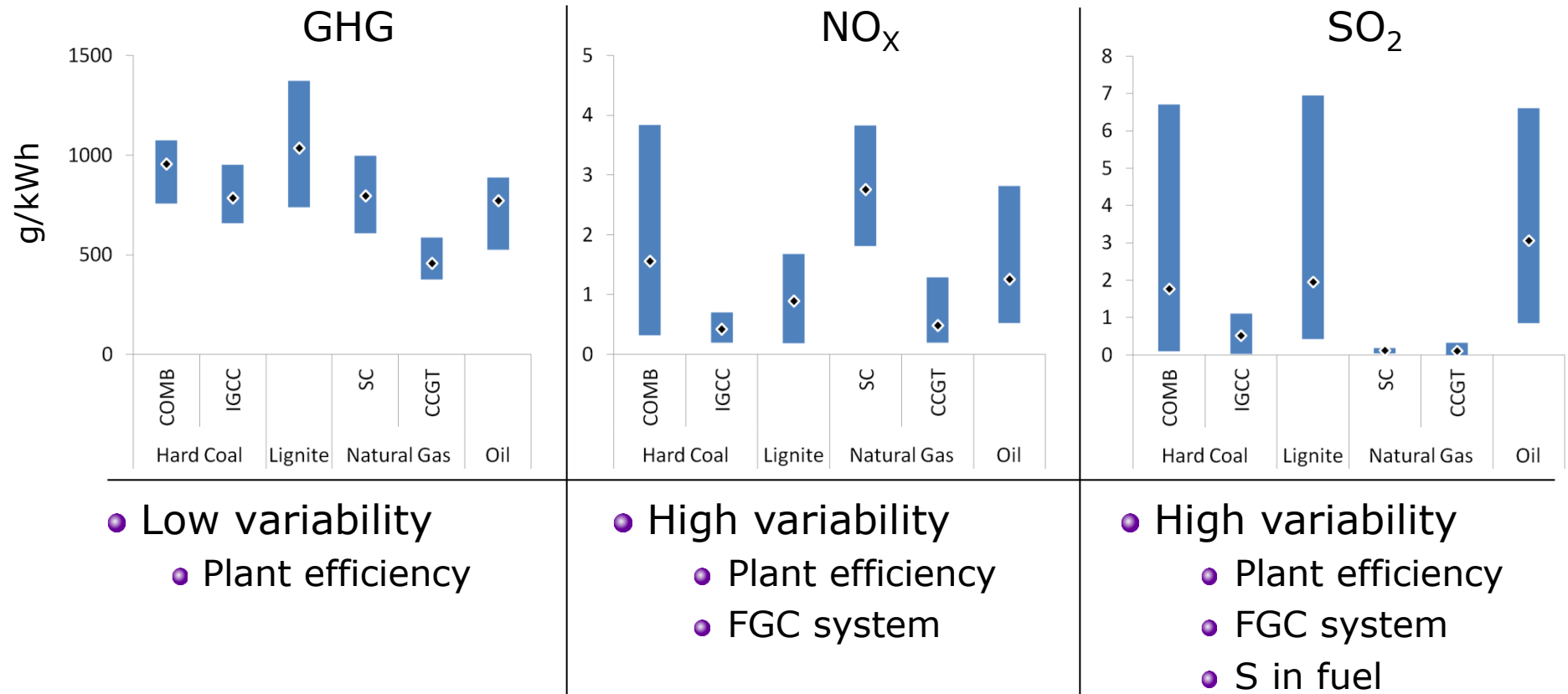
## Objective of the study

- Research question: **What are the key parameters determining the environmental impacts of an energy generation technology?**
- Complementary to **NREL Harmonization study**
  - NREL: “Energy modeler” point of view
    - (**GHG**) Reduce variability → Define average values
  - This study: “LCA practitioner” point of view
    - (**LCA**) Find key parameters to identify a specific technology for a case study

# Methodology

- **Literature review:** 167 case studies included
- Technologies considered:
  - Hard Coal
  - Lignite
  - Natural Gas
  - Oil
  - Nuclear
  - Hydro
  - Solar PV
  - Wind
  - Biomass
- Emissions considered: GHG, NO<sub>x</sub>, SO<sub>2</sub>
- Focus on **technological** and **methodological** aspects

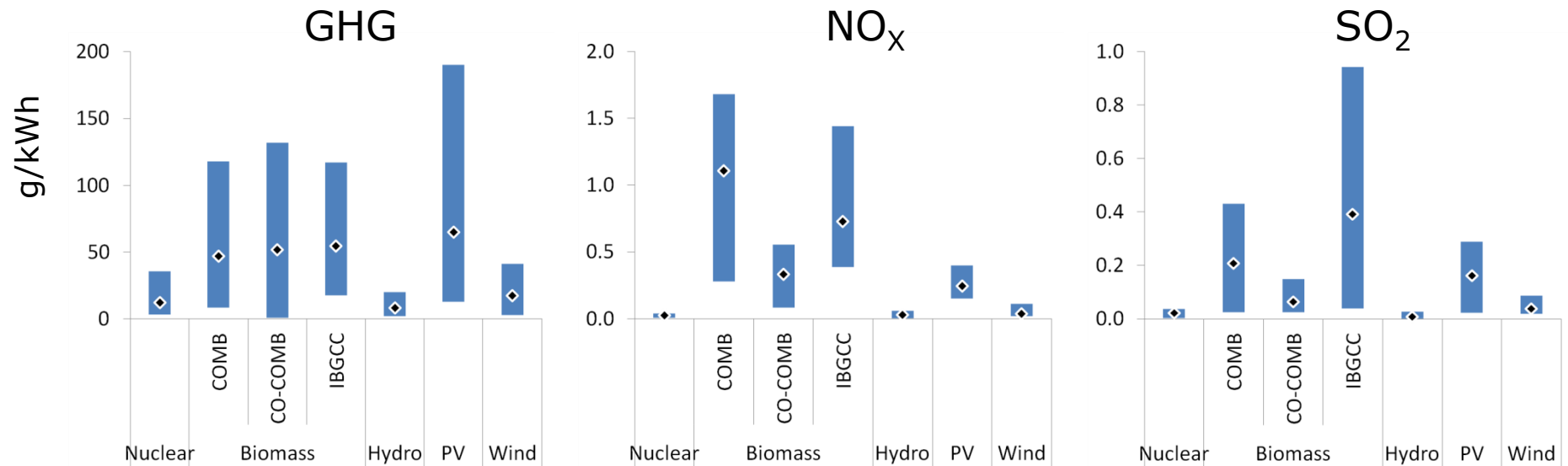
# Results – Fossil Fuels



• Main contributor: Direct emissions

• No methodological issues

# Results – Nuclear and renewables



| Technology            | Main contributor | Sources of variability                             |
|-----------------------|------------------|--|
| Nuclear               | Fuel provision   | Fuel enrichment, el. mix, methodology (IOA vs PCA) |
| Hydro, Wind, Solar PV | Infrastructures  | Type, electricity mix, methodology (IOA vs PCA)    |
| Biomass               | ?                | Combination of methodology and technology          |





# Why LCA rather than only GHG?

## Hotspots definition

Example: Natural gas

|                     |                  |     |
|---------------------|------------------|-----|
| • GHG:              | Direct emissions | 83% |
| • NO <sub>x</sub> : | Fuel provision   | 54% |
| • SO <sub>2</sub> : | Fuel provision   | 96% |

## Problem shifting

|                 |             |  |          |       |
|-----------------|-------------|--|----------|-------|
| Example:        | Natural gas | vs   | Oil      |       |
| GHG             | 380-1000    |     | 530-900  | g/kWh |
| SO <sub>2</sub> | 0.01-0.32   |   | 0.85-8   | g/kWh |
|                 | Solar PV    | vs   | Biomass  |       |
| GHG             | 8.5-130     |   | 13-190   | g/kWh |
| NO <sub>x</sub> | 0.15-0.40   |  | 0.08-1.7 | g/kWh |



# Discussion

| Technology                       | Technological factors   | Methodological factors  |
|----------------------------------|---|---|
| <b>Fossil fuels</b>              | Efficiency,<br>FGC (NO <sub>x</sub> and SO <sub>2</sub> ),<br>Fuel quality (SO <sub>2</sub> ) | -   |
| <b>Nuclear</b>                   | Electricity mix,<br>fuel enrichment   | IOA vs PCA data   |
| <b>Hydro, Wind,<br/>Solar PV</b> | Electricity mix,<br>reference year  | IOA vs PCA data   |
| <b>Biomass</b>                   | Type, quality, origin<br>of the feedstock   | Multi input/output<br>system, land use,<br>constrained resource |

# Conclusions

- Existing literature: may be confusing
  - studies often built on different assumptions/approaches/technologies
- **What are the key parameters determining the environmental impacts of an energy generation technology?**
  - Technological and methodological aspects
    - Differ from one technology to another
    - Depend on the impact category
  - **LCA needs Transparency and Comprehensiveness**

**Thanks for your attention.**

***Questions?***

Turconi, R., Boldrin, A., Astrup, T. - **Life cycle assessment (LCA) of electricity generation technologies: overview, comparability and limitations.** *Submitted to Renewable and Sustainable Energy Reviews.*

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